Space Weather Technical Forecast

Issued on Sunday, 12 May 2024 at 13:12 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: G4 (Severe) Geomagnetic storms expected with a Chance of G5 (extreme) Geomagnetic storms 12 May, conditions may continue 13 May but a general waning of activity expected through the period. Further R3 (Strong flares) likely.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has remained High in the past 24 hours, with X-ray activity recorded at GOES16 showing frequent M-class activity, peaking with an M8.8 flare from AR3664 at 11/1525 UTC. There are currently nine sunspot groups on the visible disc, with a new and unnumbered region which has rapidly emerged in the southeast disc.

AR3664 is by far the largest and most complex region on the disc, which has been the case over recent days. It currently presents as a Zurich Fkc with Mt Wilson Beta-Gamma-Delta classification. Although growth of the region has slowed, there has been consolidation of the broader penumbral area and notable relative movement between the various mixed polarity spots, presenting large magnetic shear and further potential for strong flares. There are numerous Mt Wilson deltas present. The remaining regions on the visible disc are much smaller and more magnetically simple.

The X3.9 and M5.9 flares of AR3664 on 10 May both resulted in CMEs that are Earth directed. The former is expected to sweep up a previous CME to arrive at Earth early on Day (12 May), which may have recently arrived at L1 as a weak feature. The X5.8 flare which released a CME is anticipated to arrive later on Day 1 (12 May). A further CME associated with the M8.8 flare from AR3664 at 11/1526 UTC may arrive on the 13 May, which is still being analysed.

Solar Wind / Geomagnetic Activity: The solar environment has been enhanced over the past 24 hours following the two CME impacts late on the 10 May. Solar winds, as observed by ACE at L1, have been mostly at very strong levels throughout the period, with a peak of 996km/s at 12/0100 UTC, with a steady decline down to 830km/s, before a recent jump back up to 900km/s due to a weak CME arrival observed at 12/0855UTC at L1/ACE data. Solar wind density has been mostly average to above average, with a peak of 12ppcc at 12/0335 UTC. The IMF started the period at very strong levels, with a peak of +28nT observed at 11/1220 UTC, before a steady decline down to weak levels, although a recent jump to Moderate levels has been observed at 12/0855 UTC due to a weak CME arrival. The north-south component (Bz) also started the period strongly negative (southward) with a peak of -25nT observed at 11/1229 UTC, but has now become weakly positive (northward). The phi angle was variable throughout, but overall favoured towards positive (away from the Sun).

The net result of the above solar wind measures was an Extreme storm (G5/Kp9) interval observed at 11/1200-1500 UTC, with Severe storm (G4/Kp8) intervals between 11/1500-2100 UTC, declining to Strong Storm (G3/Kp7) between 11/2100-0000 UTC and 12/0000-0600 UTC, before finishing at the current Unsettled (Kp3) levels.

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Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) observed at GOES18 remained above the S1 threshold in the wake of strong flares, with mostly S1/Minor storm levels being maintained.

High energy electron flux (greater than 2MeV) observed at GOES16 was at normal background to moderate levels. The associated 24-hour fluence was well below the Active threshold. Observed fluence at 12/0001 UTC was 2.58e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Further X-class flares are probable in the coming days with frequent M-class flares expected, primarily from AR3664, but perhaps also contributed to from new eastern solar horizon arrivals.

Solar Wind / Geomagnetic Activity: Recent CME arrivals have significantly increased geomagnetic activity and solar winds (strong to very strong) and further CMEs are expected to follow in the coming days. Two large flares from AR3664 on 09 May resulted in Earth-directed CMEs. The faster, second CME is forecast to merge with the preceding CME resulting in a combined front arriving during Day 1 (12 May). Another much slower CME was observed leaving the sun following another large flare of AR3664 on 10 May. Another faster CME from the X5.8 flare is anticipated to impact the Earth later on Day 1 (12 May). A further CME associated with the M8.8 flare from AR3664 at 11/1526 UTC may arrive on the 13 May, but this is awaiting further analysis - pending results.

Geomagnetic activity has subsided in recent hours, down to Unsettled (Kp3) levels. Activity may become enhanced again following the expected combined arrivals of the two CMEs during Day 1, one of which, may have already arrived as a weak feature at L1. Peak G4/Strong-Severe levels of activity are likely through Day 1, with a chance of G5/Extreme activity following further CME enhancement, perhaps declining at times between CME impacts during Day 1. Activity expected to wane through Days 2 and 3 (13 and 14 May), however confidence at the end of the period is low and the forecast may change should further large Earth-directed CMEs occur.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) is at S2/Moderate Storm levels and should be maintained into Day 1 (11 May) at least, with a somewhat uncertain decline projected in the absence of any further significant flaring from AR3664. The region is, however, moving into a more favourable location for proton response in the coming days. There is a chance of S3/Strong or greater levels on Days 1 and 2 (11 and 12 May) reducing to a slight chance on the remaining days, although this could change following any further large flares from AR3664.

High energy electron flux is forecast to be at normal background levels throughout, with associated fluence expected to remain well below the Active (1e8 integrated pfu) threshold. Although there is a slight chance electrons could start to become enhanced towards the end of the period.

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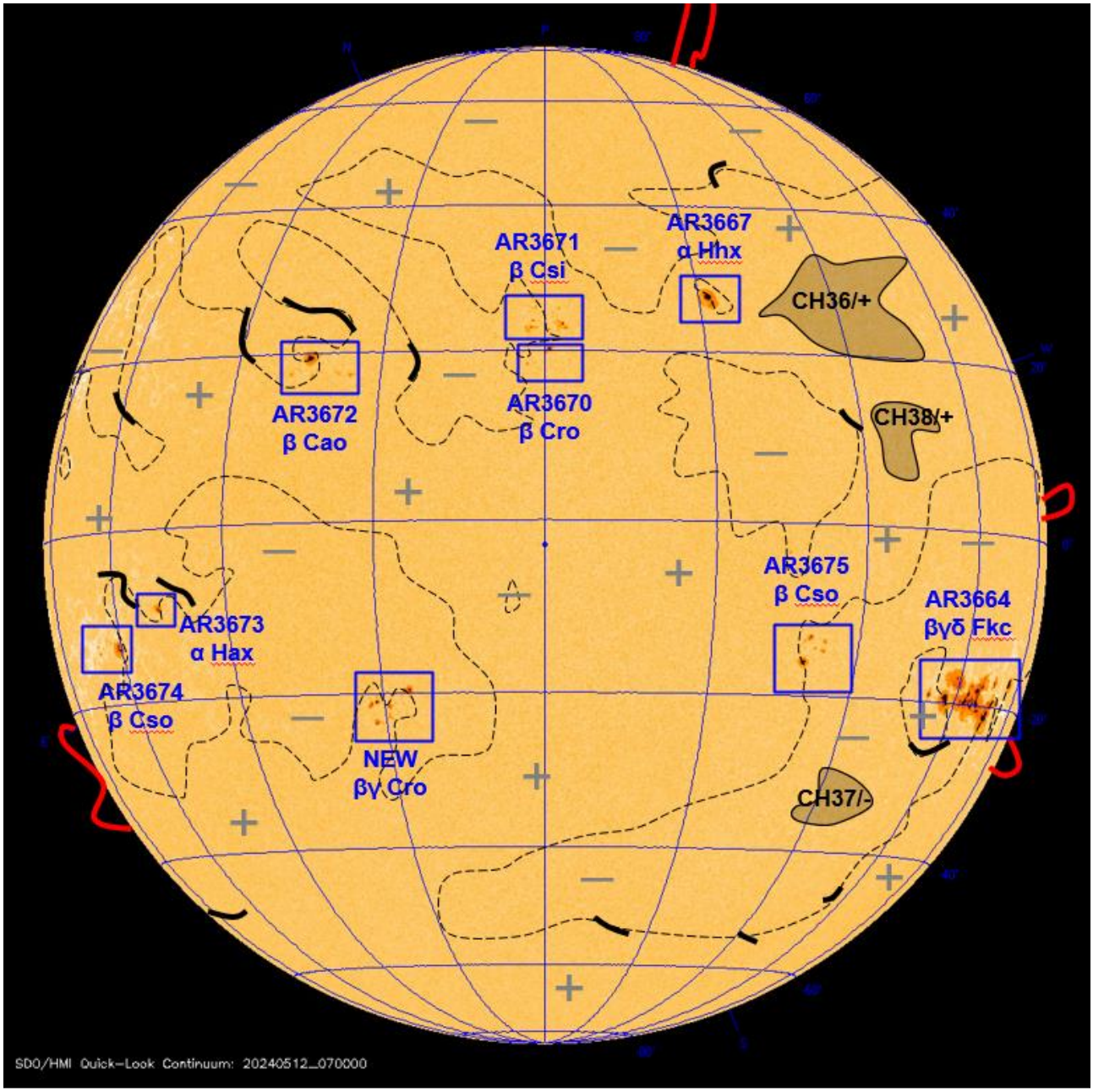
Figure 1. Solar Analysis Valid 12/0700 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Multiple CME arrivals were detected at L1 on 10 May, with CME influence on going through the 11 May, with further Earth-directed CMEs expected in the coming days. A CME associated with the X1.1 flare of AR3664 at 09/1743 UTC, is expected to be 'swept up' by the faster CME from the X3.9 flare of the same region at 10/0654 UTC. This is expected to result in a combined arrival at Earth on Day 1 (12 May). Another CME was observed leaving the sun following the M5.9 flare of AR3664 at 10/1411 UTC. A large halo CME was observed from the large X5.8 flare at 11/0123 UTC and this is anticipated to arrive later on 12 May. A further CME associated with the M8.8 flare from AR3664 at 11/1526 UTC may arrive on the 13 May, but this is awaiting ENLIL analysis.

Other drivers of geomagnetism from coronal hole enhancements are expected to be masked and pale in comparison to the ongoing CME effects. A minor coronal hole enhancement may have contributed to the enhanced geomagnetic activity observed at Earth, although this (CH38/+) may well have opened too late for any arising fast wind to intersect the Earth, which would delay the inbound fast wind to the larger and more intense CH36/+ later on Day 2 (12 May). Small CH37/- in the southern hemisphere may also connect with Earth in a similar timeframe.

Geomagnetic activity has subsided in recent hours, down to Unsettled (Kp3) levels. Activity may become enhanced again following the expected combined arrivals of the two CMEs during Day 1, one of which, may have already arrived as a weak feature at L1. Peak G4/Strong-Severe levels of activity are likely through Day 1, with a chance of G5/Extreme activity following further CME enhancement, perhaps declining at times between CME impacts during Day 1. Activity expected to wane through Days 2 and 3 (13 and 14 May), however confidence at the end of the period is low and the forecast may change should further large Earth-directed CMEs occur.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	100	70	50	20
Strong	G3	Yes	100	40	10	1
Severe	G4	Yes	95	30	1	1
Extreme	G5	Yes	50	20	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
09/2219	Full	AR3664	SW	888 km/s	12/0100 UTC	Swept up by second CME
10/0950	Full	AR3664	SW	1170 km/s	12/0100 UTC	Sweeps up first CME
11/0443	Full	AR3664	SW	1250 km/s	12/1800 UTC	Bulk of ejecta to the W

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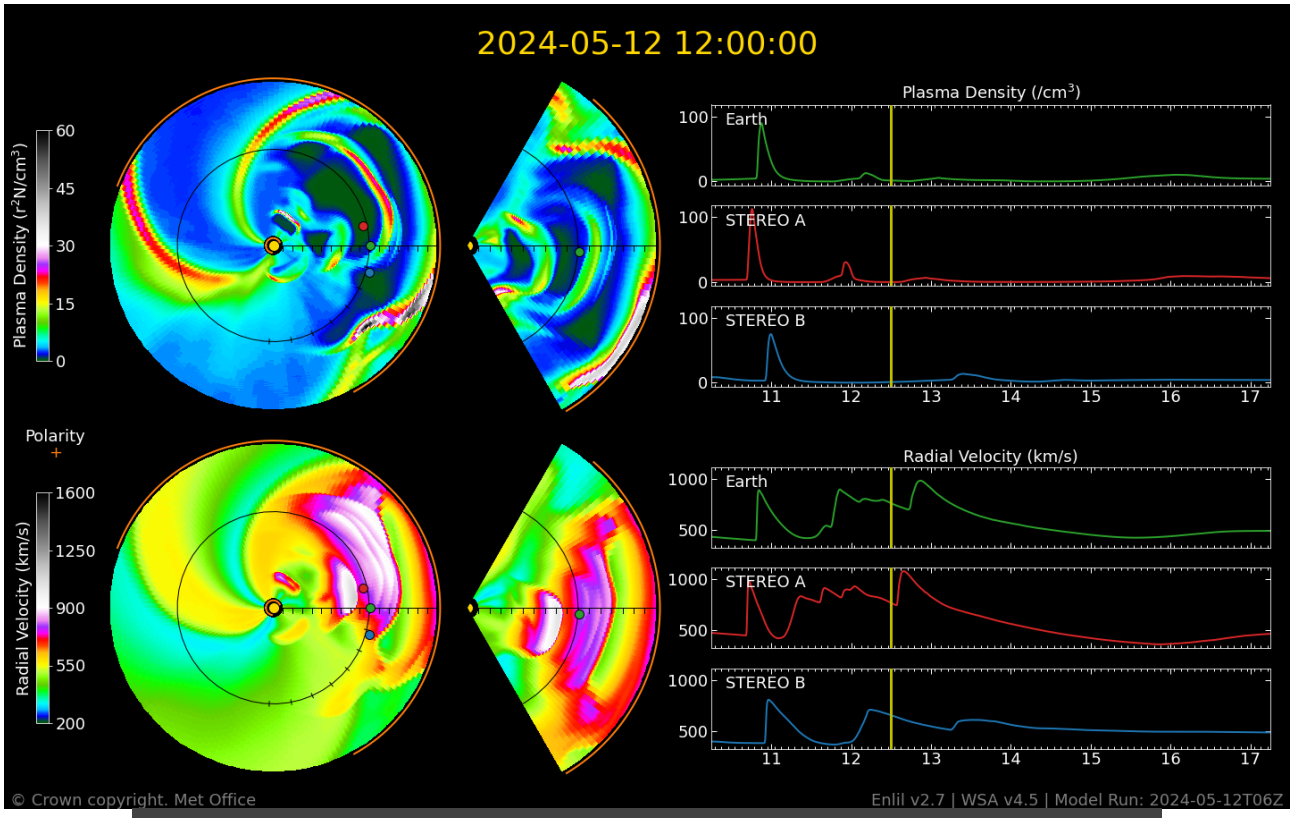
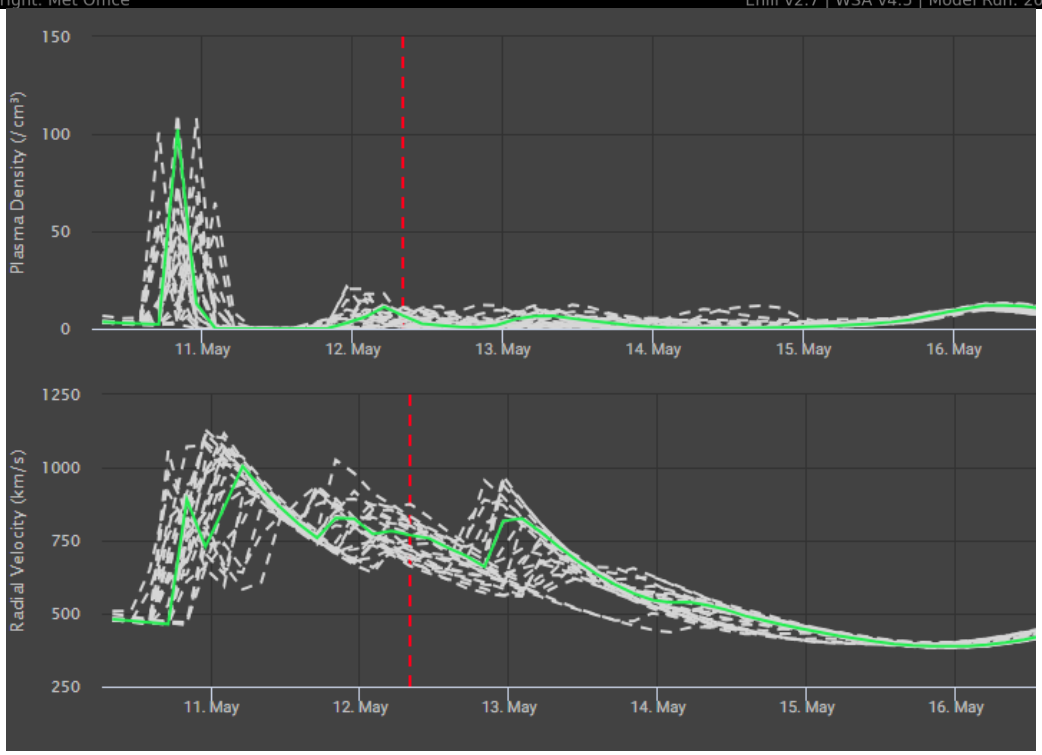
Figure 2: MOSWOC Enlil and ensemble – shows possible CME arrivals during 12-13 May.





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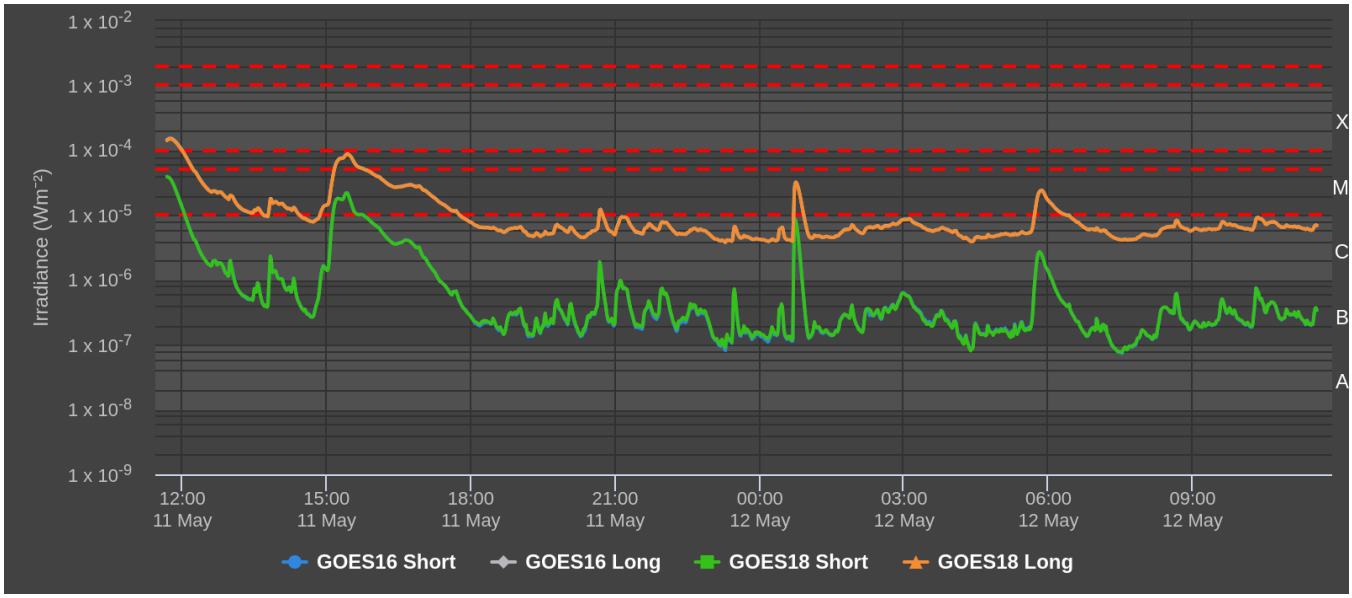
Radio Blackouts - X-Ray Flares:

Solar activity for much of the past UTC working week has been dominated by the large and complex regions Ex-AR3663 and AR3664. Ex-AR3663 has now rotated over the northwest horizon, though still poses a slight risk for further significant flares in the near-term. AR3664 will persist on the visible disc until the end of day 2 (13 May). There are signs of another large sunspot region near the southeastern solar horizon. There is an initial slight decrease in the risk of R3 given the departure of Ex-AR3663, however the fact that X-ray flux has resided within M-class for much of the period means the Expected risk of R1/R2 remains largely unchanged. Any contribution from the eastern solar horizon will be factored in as and when regions present for analysis.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	95	95	90	40
Very Active	R3 to R5 X Class	No	60	60	50	20

Figure 3: GOES X-Ray flux trace.



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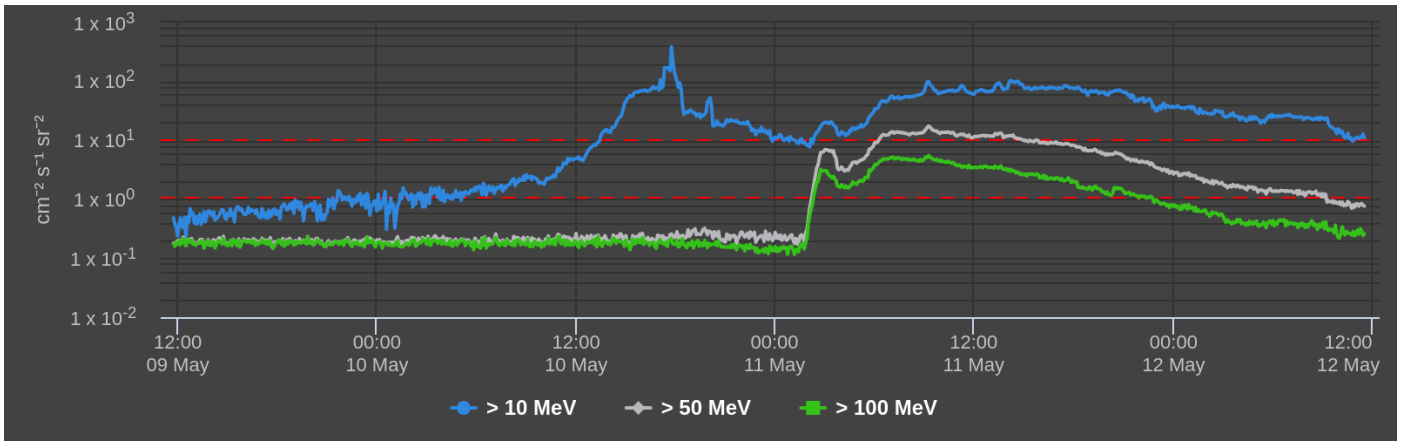
Solar Radiation Storms - (High Energy Protons):
High energy proton flux (greater than 10MeV) observed at GOES18 has increased in response to active flaring of AR3664 and the arrival of multiple CMEs on 10 May. S1/Minor Storm levels should be maintained through Day 1 (12 May), with a somewhat uncertain decline projected in the absence of any further significant flaring from AR3664. The region is, however, moving into a more favourable location for proton response in the coming days. There is a chance of S2/Moderate or greater levels on Day 1 (12 May) reducing to a slight chance on the remaining days, although this could change following any further large flares from AR3664.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	60	40	20
Very Active	**≥ S3 ***	No	25	15	10	5
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES16 Proton Flux over the past 3-days – shows a gradual declining trend following the recent strong flares from AR3664 in the southwest.



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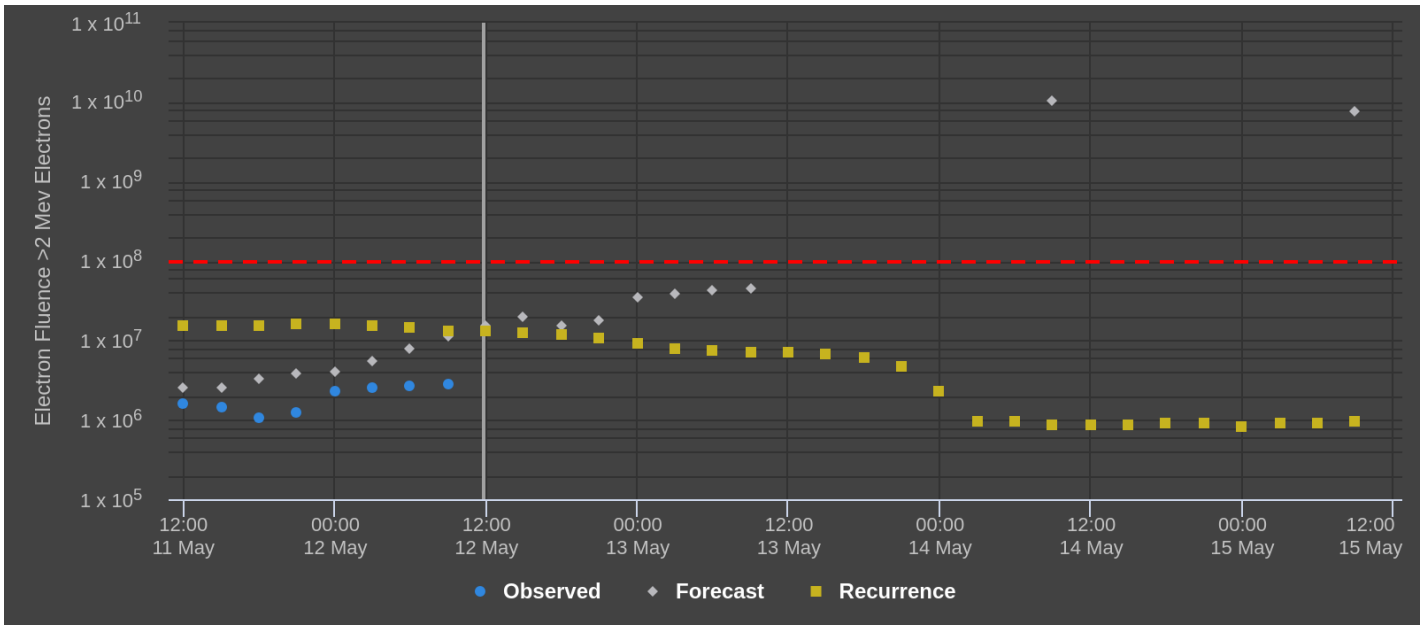
High Energy Electrons Event (≥ 2MeV):
High energy electron flux at GOES16 is at normal Background levels, and is expected to remain at or near this level given the number of inbound CMEs and the likely sustained pressure on the Van Allen belts sweeping them inside GEO for some time. However there is a slight chance that electrons could become enhanced towards the end of the period, in absence of further CME enhancements.

Overall, the 24-hour integrated electron fluence is forecast to remain well below the Active (1e8 integrated pfu) threshold. The Met Office REFM is not considered to offer useful guidance in the coming days by anything other than chance given the CME-dominated forecast.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	10	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: MOSWOC REFM electron fluence



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